

VISIT...

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Brain-Computer Interfaces for Interaction and Control

José del R. Millán

Defitech Professor of Non-Invasive Brain-Machine Interface

Center for Neuroprosthetics

Institute of Bioengineering, School of Engineering

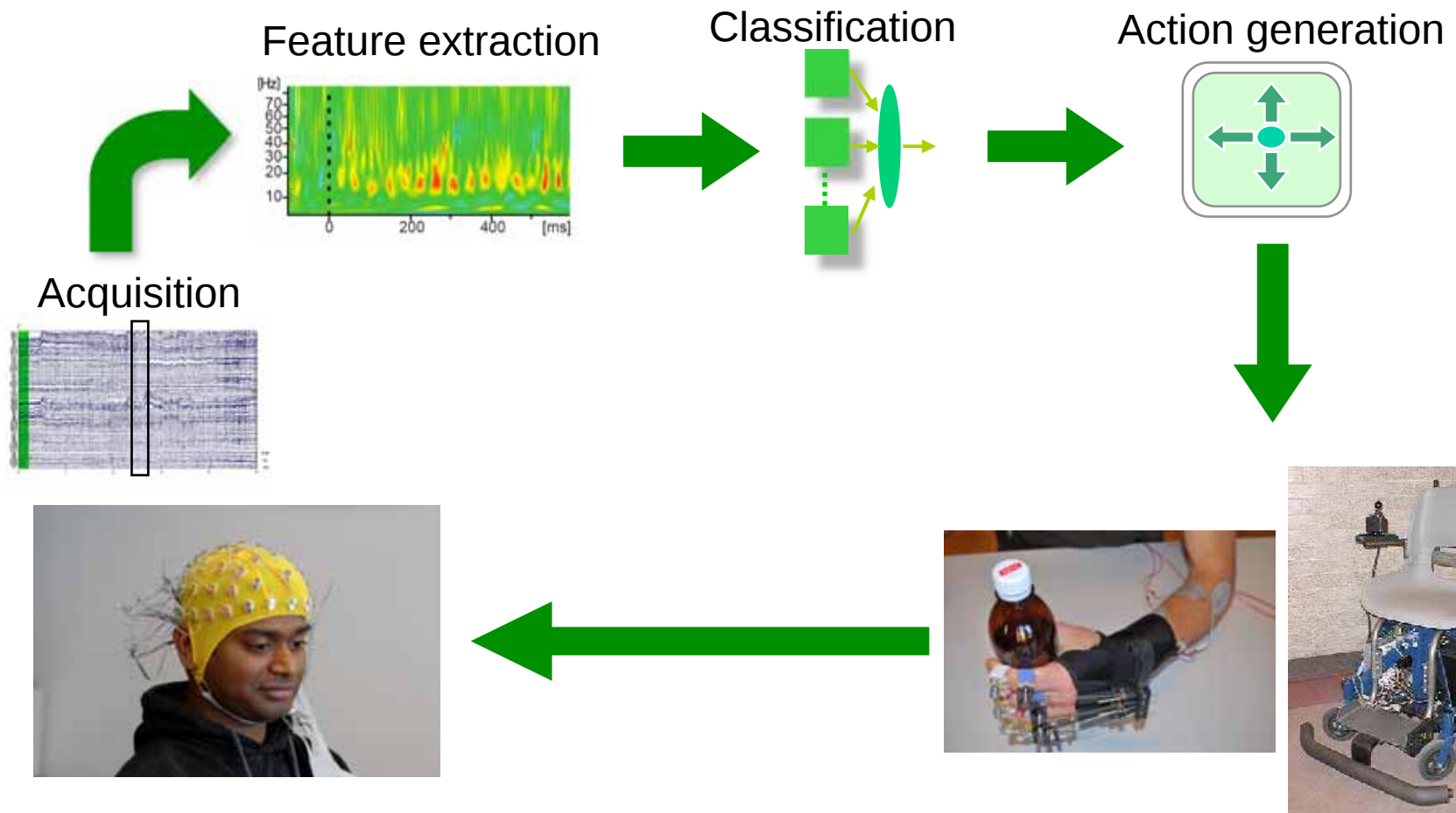
Swiss Federal Institute of Technology Lausanne

jose.millan@epfl.ch



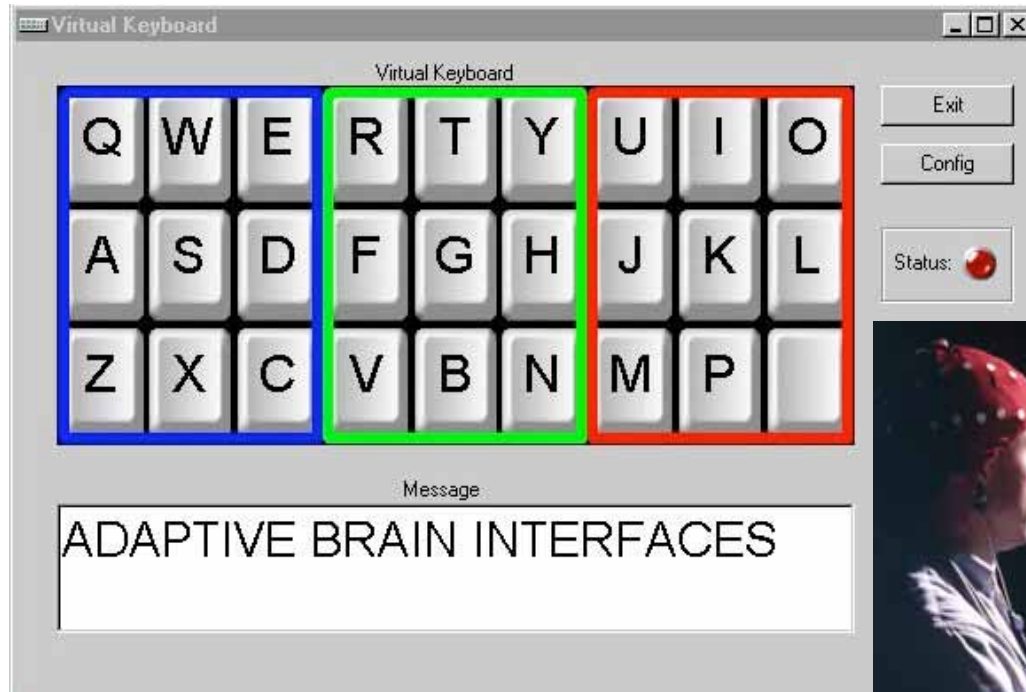


BCI Architecture





Brain-actuated Virtual Keyboard



*ABI Project
1998-2001*



- *Asynchronous protocols*
- *Machine learning approaches*



Brain-actuated Computer Game



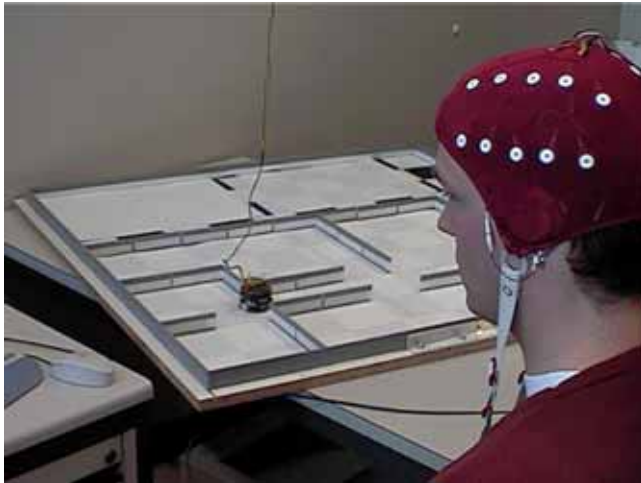
*ABI Project
1998-2001*



- *Asynchronous protocols*
- *Machine learning approaches*



Brain-controlled Robots



➔ big challenge,
fast and timing decision-
making is critical

- *1st demonstration of brain-controlled robots & wheelchairs*
- *Novel principles to design intelligent neuroprosthetics*



Brain-controlled Robots

*MAIA Project
2004-2007*

- *1st demonstration of brain-controlled robots & wheelchairs*
- *Novel principles to design intelligent neuroprosthetics*





TOBI — Tools for Brain-Computer Interaction

- TOBI will develop **practical** non-invasive BCI-based assistive technology endowed with **adaptive** capabilities that augment those other AT they are combined with:
hybrid architecture
- 4 application areas where TOBI technology can have a real, measurable impact in terms of pre-clinical validation, for people with motor disabilities



<http://www.tobi-project.org/>



TOBI — Partners

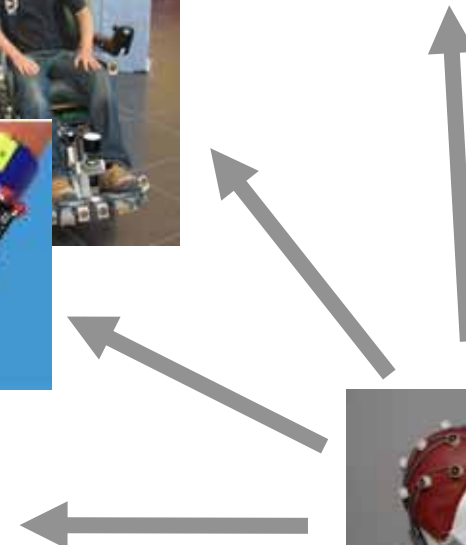
- Ecole Polytechnique Fédérale de Lausanne, CH (coordinator); **BCI, NeuroProsthetics**
- Technical University Berlin, DE; **BCI**
- Technische Universitaet Graz, AT; **BCI**
- Fondazione Santa Lucia, IT; **BCI, clinics**
- Eberhard-Karls Universitaet Tübingen, DE; **BCI, ethics**
- University Glasgow, UK; **HCI**
- QualiLife, CH; **Applied AT, industry**
- Stiftung orthopaedische Universitaetsklinik Heidelberg, DE; **NeuroProsthetics, clinics**
- Schweizerische Unfallversicherungsanstalt; CRR-Suvacare, CH; **clinics**
- Kreuznacher Diakonie; Beratungsstelle für Unterstützte Kommunikation, DE; **Applied AT, user groups**
- Associazione Italiana per l'assistenza agli spastici provincia di Bologna, IT; **Applied AT, user groups**
- Julius-Maximilian Universitaet Würzburg, DE; **BCI**





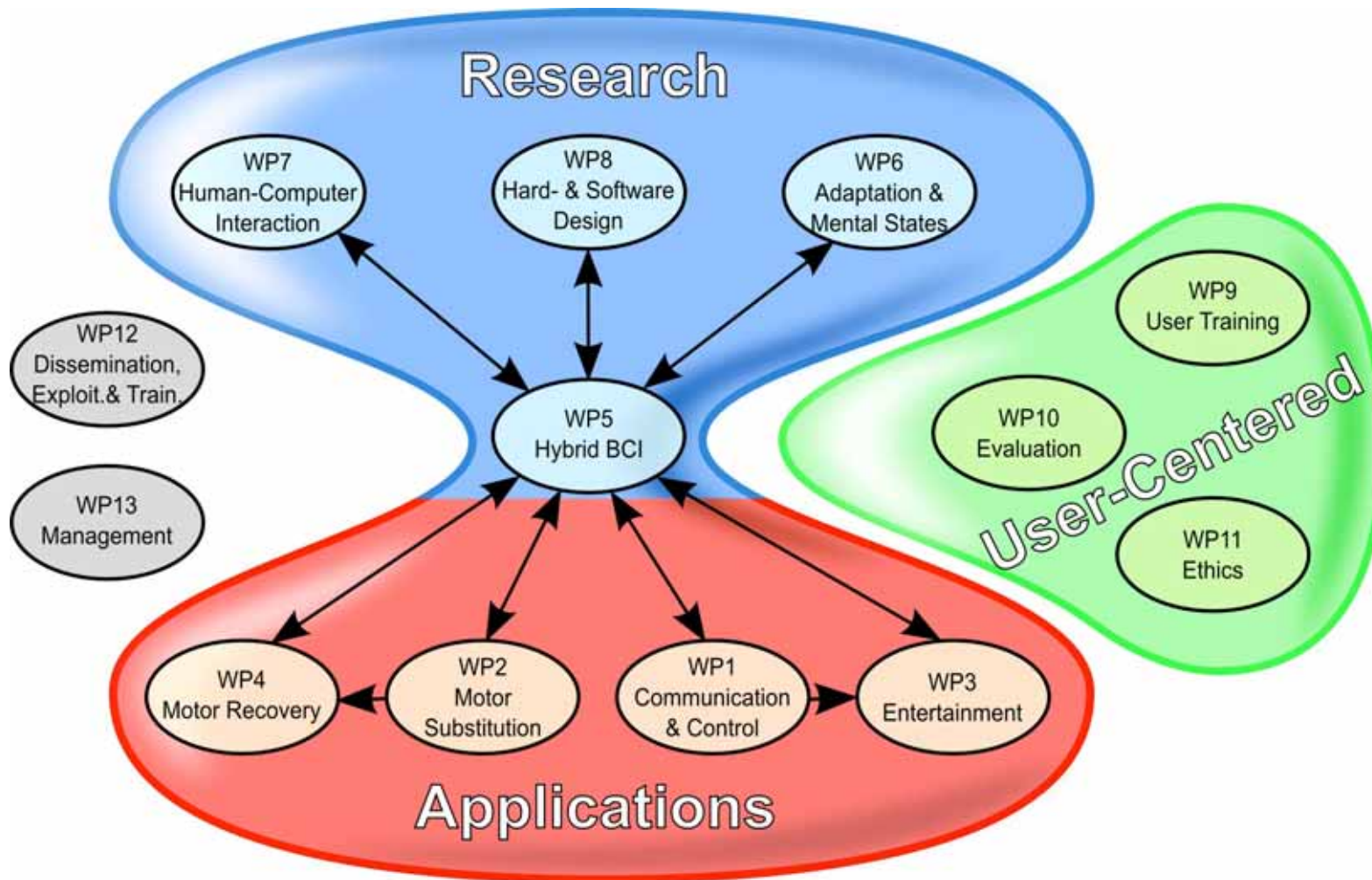
TOBI Applications

- Communication and Control
- Motor Substitution
- Motor Recovery
- Entertainment





TOBI Workpackages





User-Centered Approach — Helping Market Pick-up

User forums of end users and independent AT experts (professional users).

Testing in clinics and AT Centres starting from first prototype.

Increasing number of end users involved.

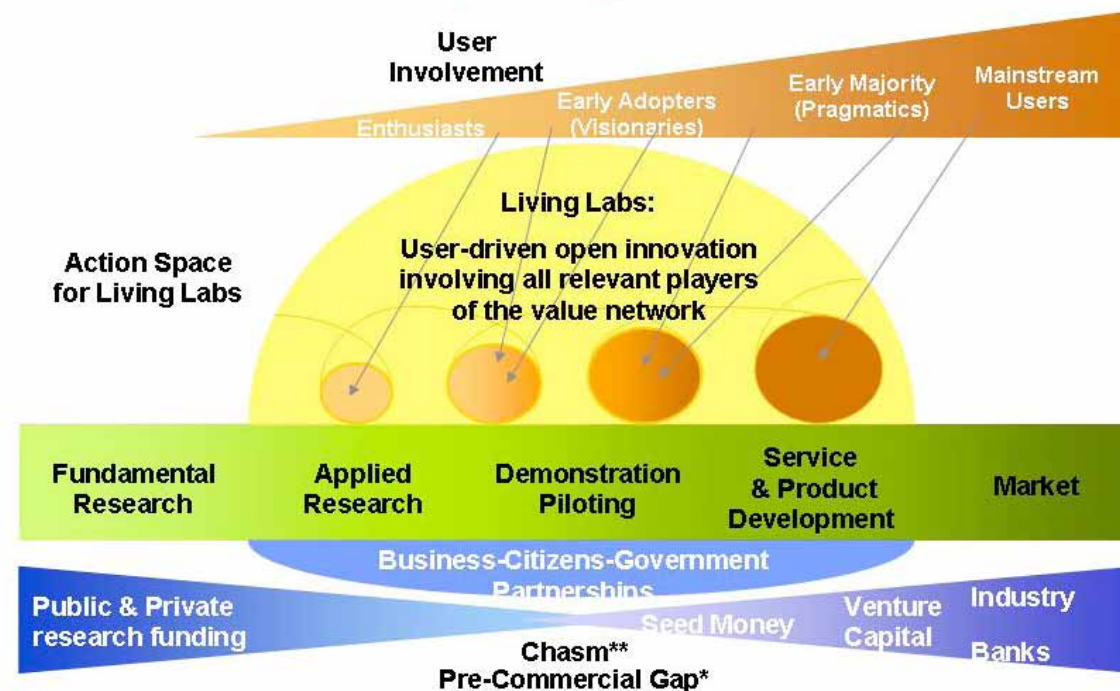
Survey into user needs

User-centered evaluation criteria and scales

Assessment expected impact on quality of life

Testing in real life situation

Action space for Living Labs along the technology adaption cycle

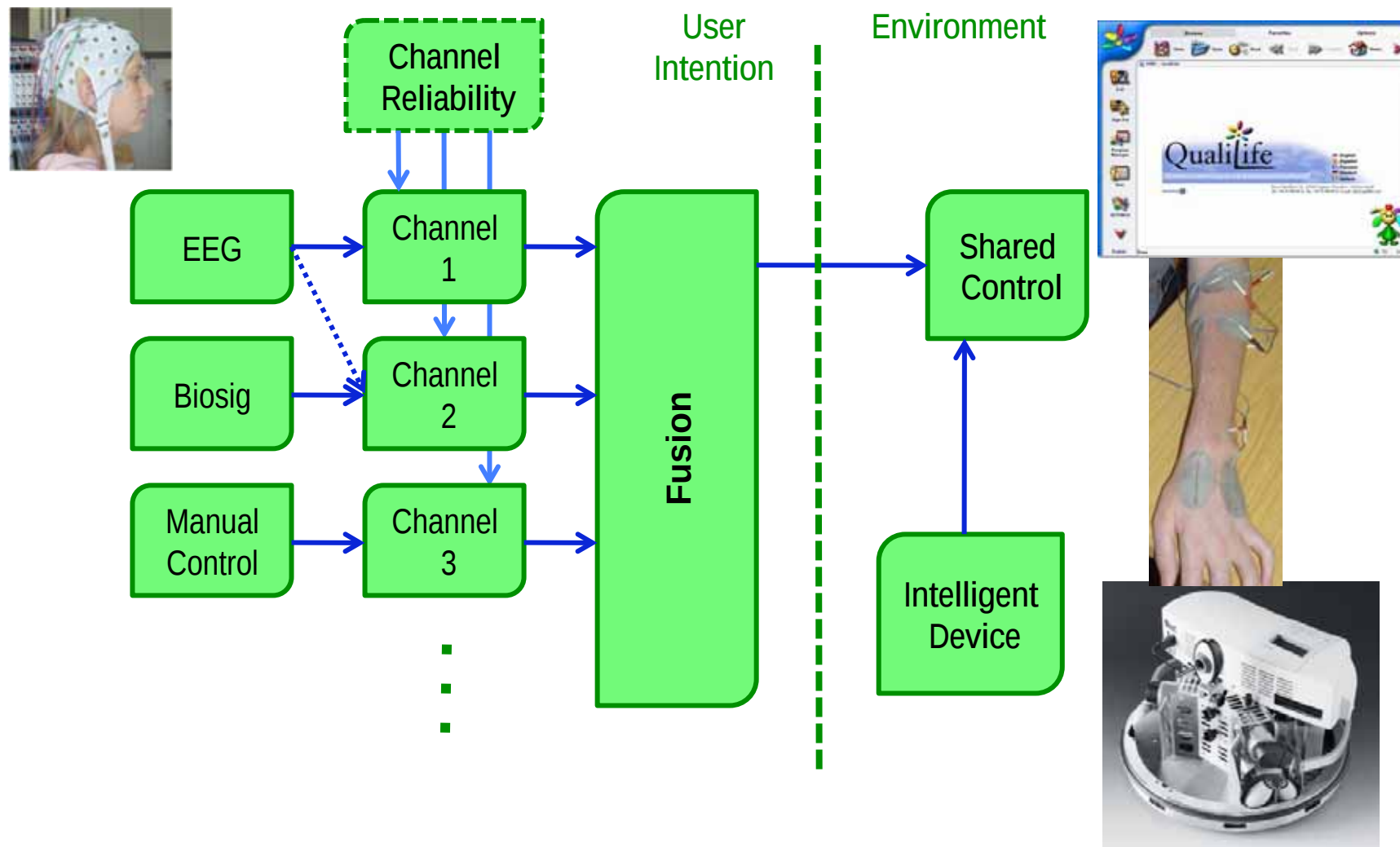


* MacDonald and Associates, 2004

** Geoffrey A Moore: Crossing the Chasm, 1999



Hybrid BCI Architecture (hBCI)





BCI at Work — A Glimpse





BCI at Work — A Glimpse





BCI at Work — A Glimpse





Interaction Principles

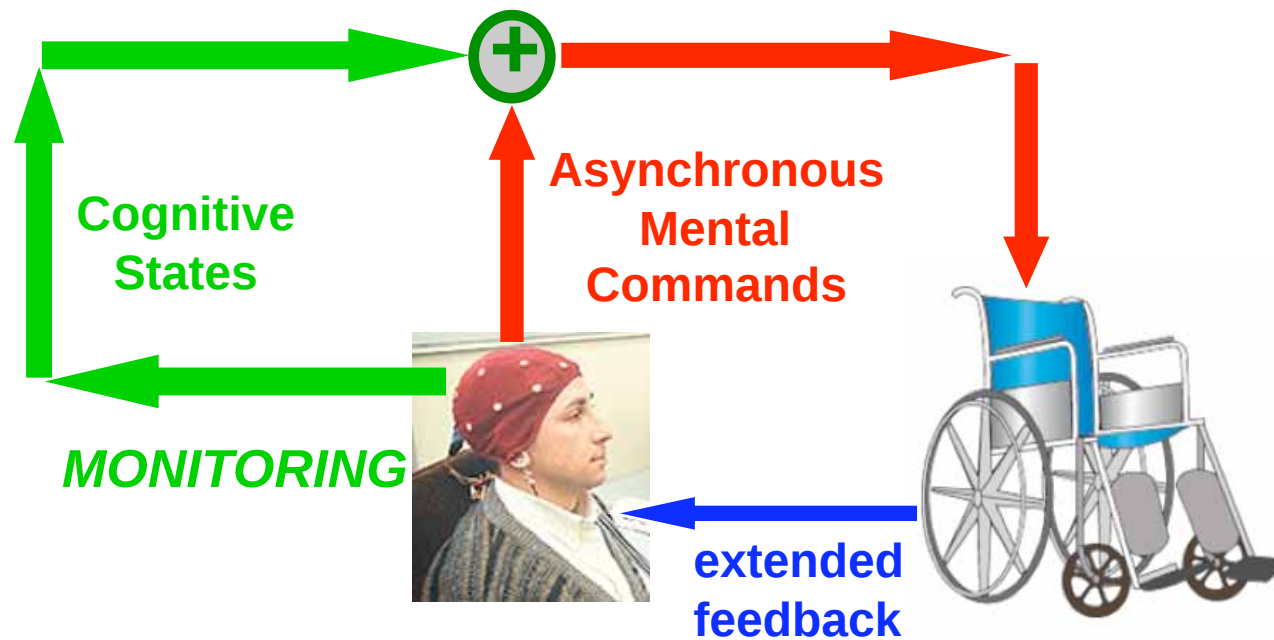


- Asynchronous approach
 - User can send commands anytime
 - Spontaneous activity, no external cues
- Machine Learning Way to BCI
 - Mutual learning process
 - Feature extraction & classification
- Blending of Intelligences
 - User's mental capabilities + intelligent device
 - Shared Control
- Cognitive Interfaces
 - Recognition of human mental states (e.g., error awareness, anticipation, fatigue)



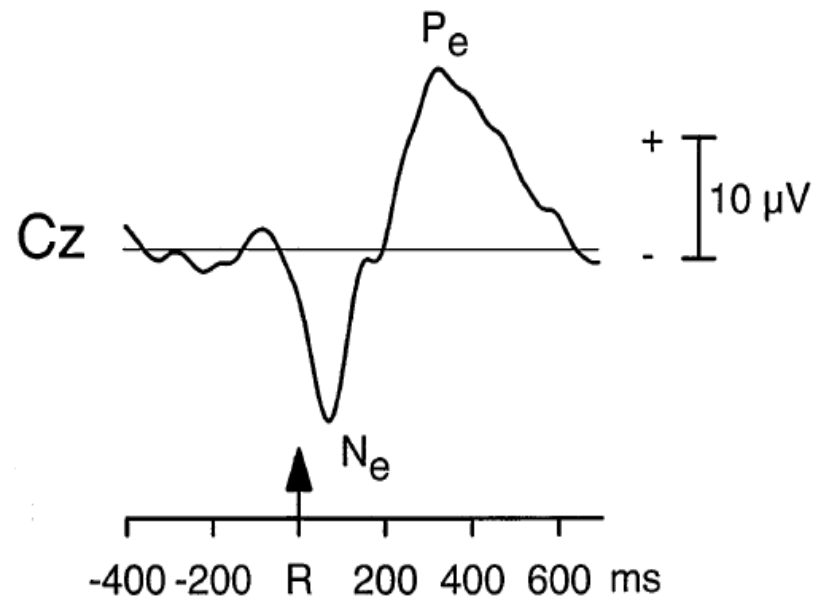


Cognitive States: Human in the Loop

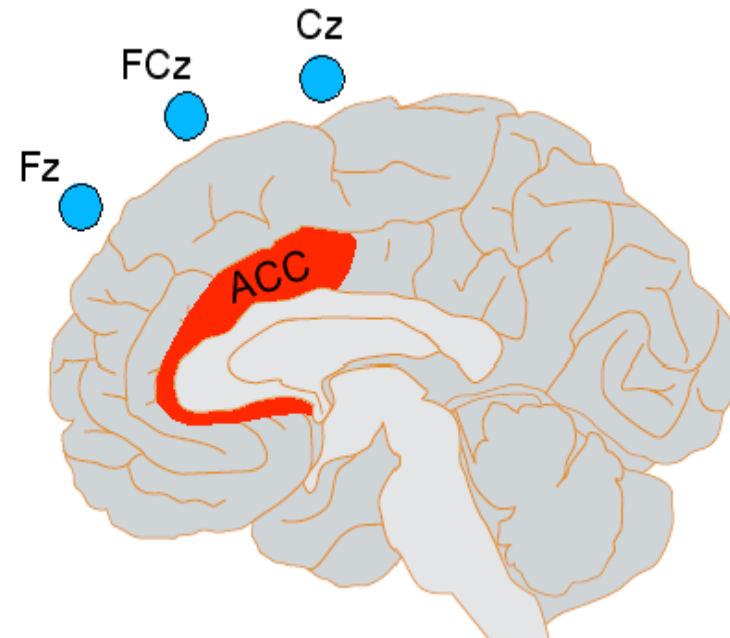




You Got Me Wrong! — Recognition of Cognitive States

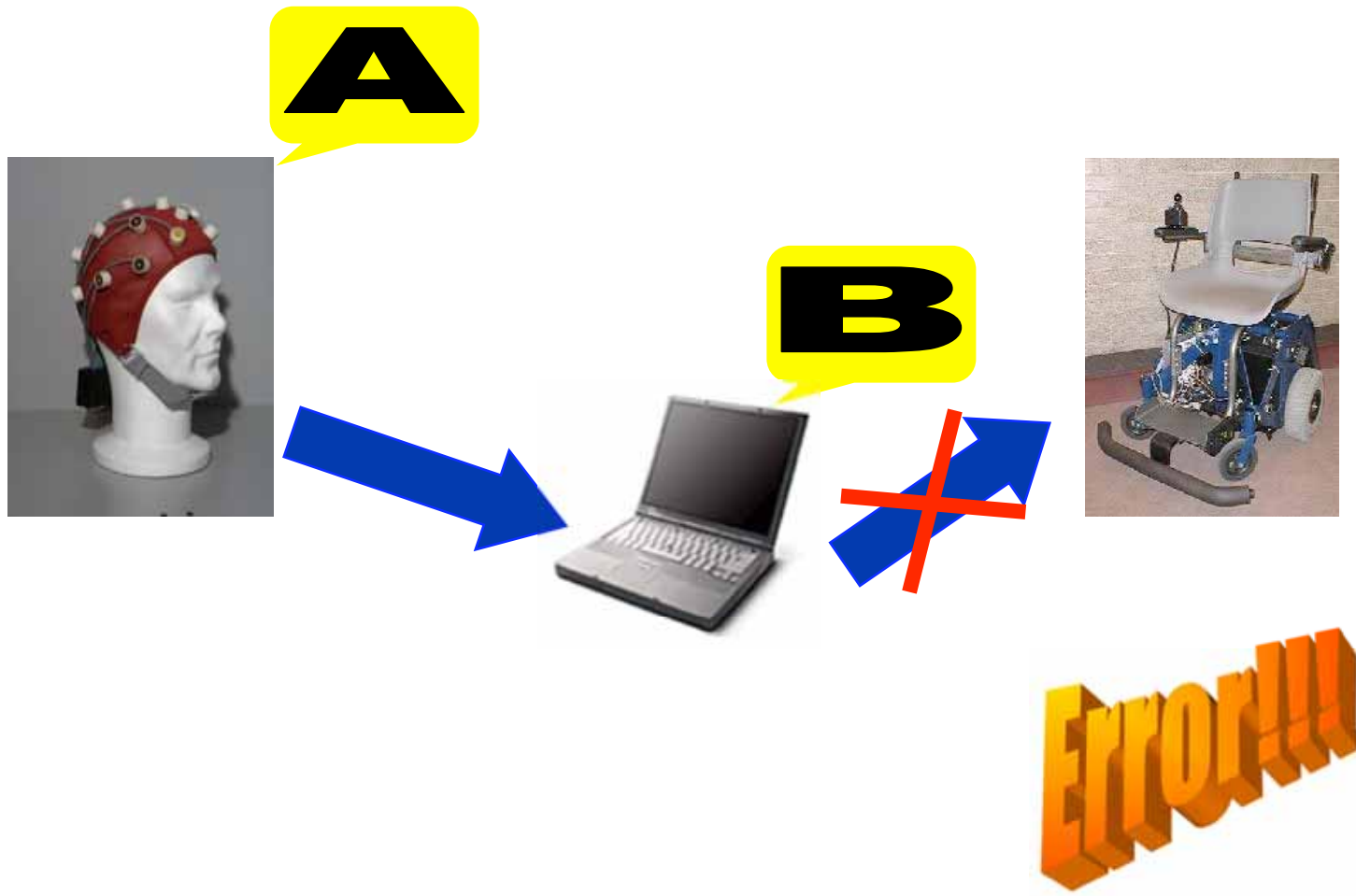


(Falkenstein et al., 2000)



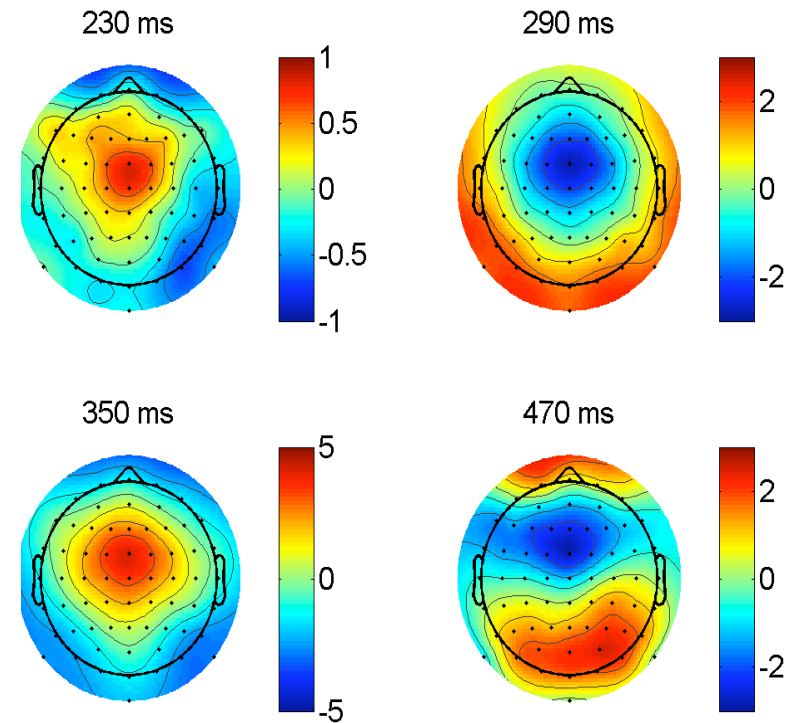
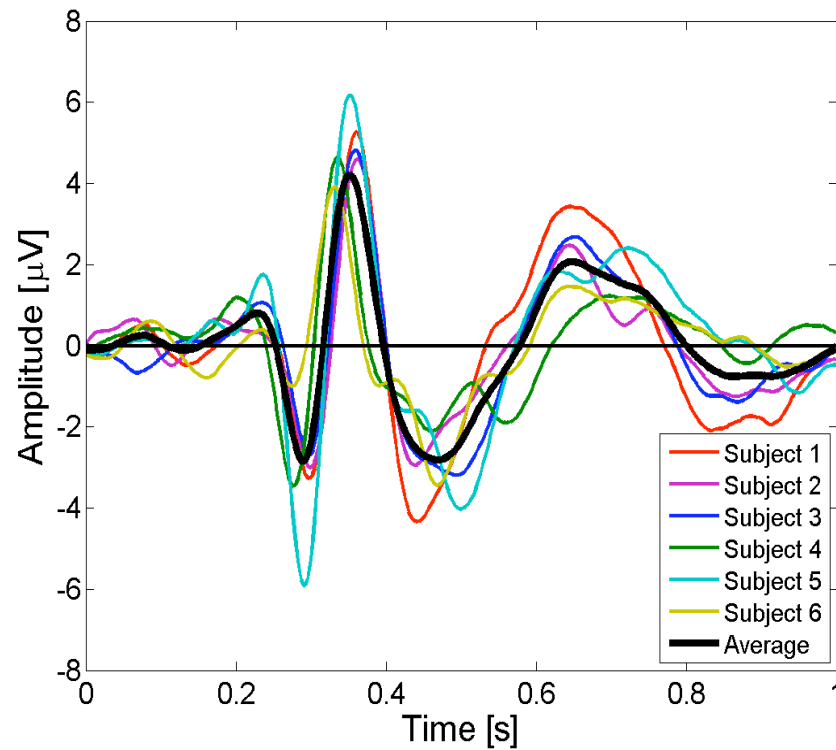


Cognitive States: Error Recognition



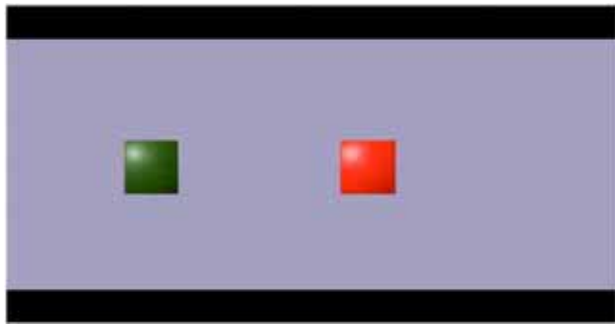


Interaction Error-related Potentials

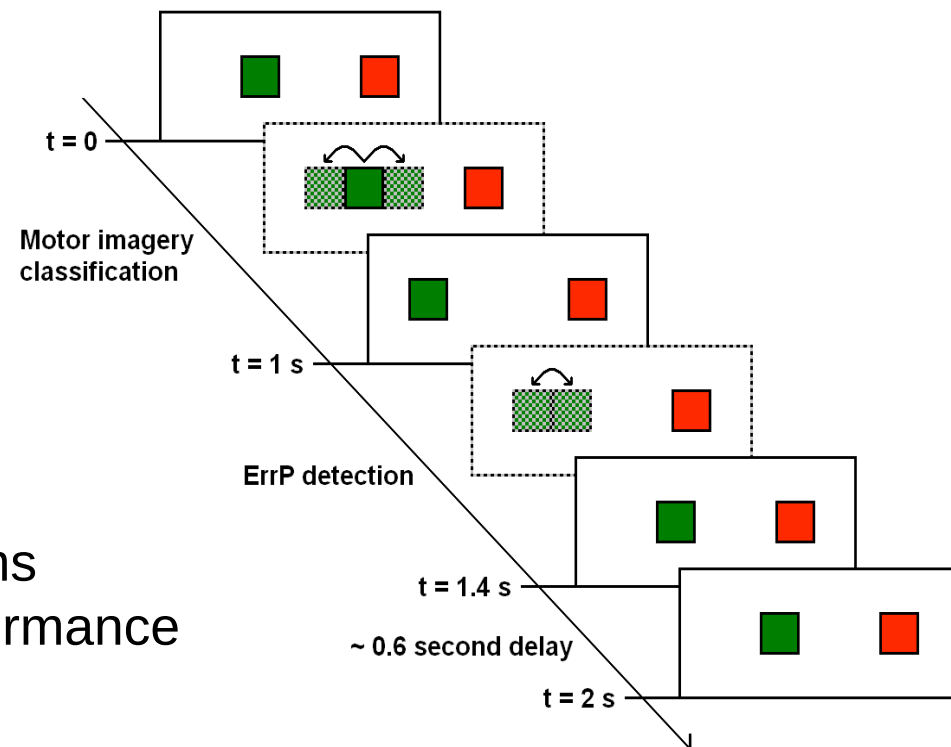




ErrP: Online Implementation



- Two naïve subjects
- Two different days
- 150 ms window: 250 $\rightarrow$ 400 ms
- Above 200% increase in performance (Bits per Trial)





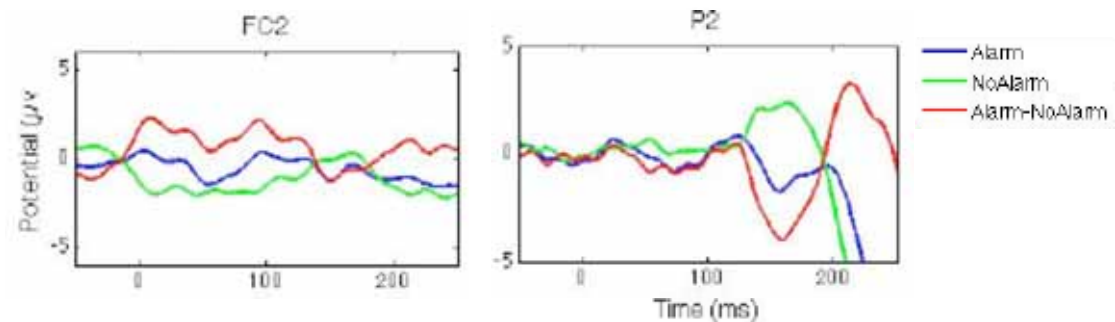
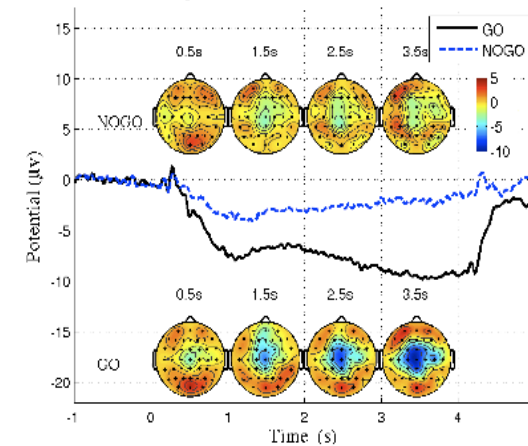
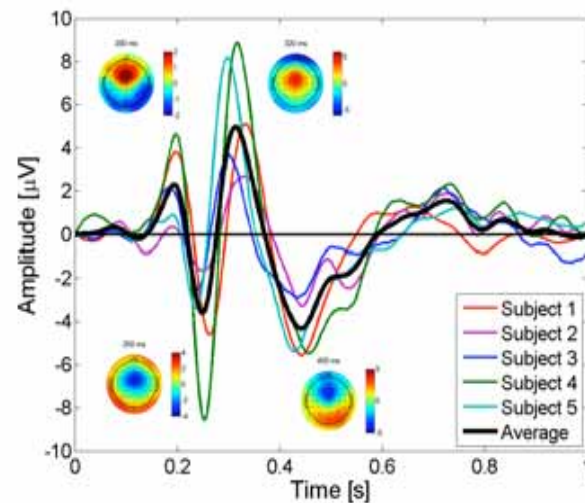
ErrP: Real-World Application





Look behind the Scene — Other Cognitive States

- error, anticipation, alarm
 ↪ trigger automatic behaviors



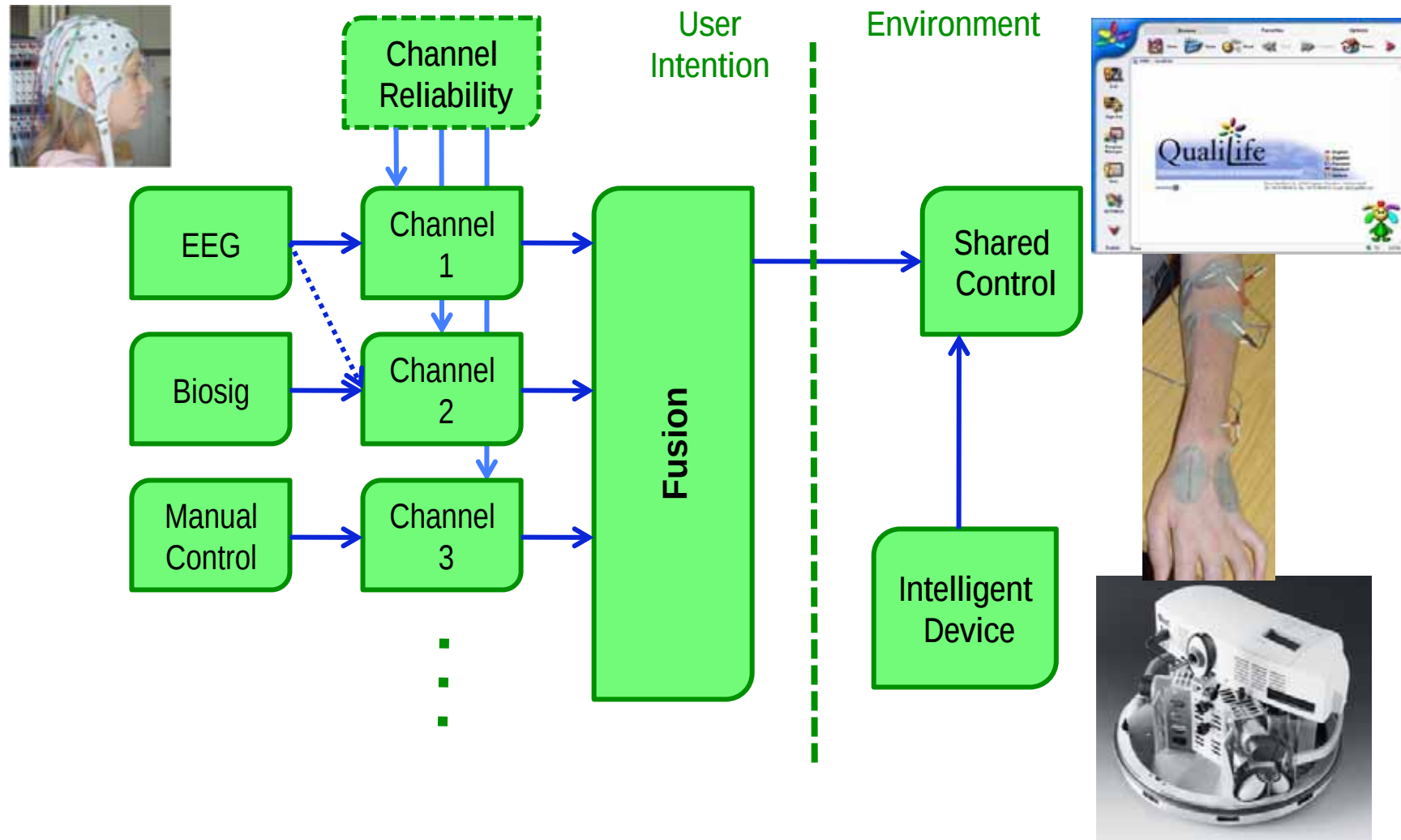


Look behind the Scene — Other Cognitive States

- error, anticipation, alarm
 - ↳ trigger automatic behaviors
- attention level, fatigue, mental workload
 - ↳ customize interaction



Hybrid BCI Architecture (hBCI)

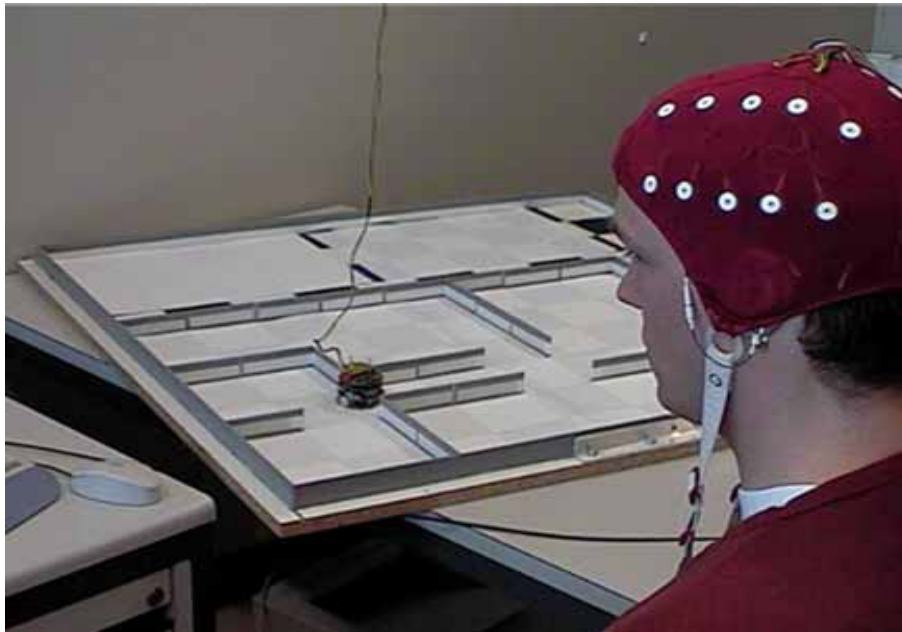




Brain-Controlled Robots

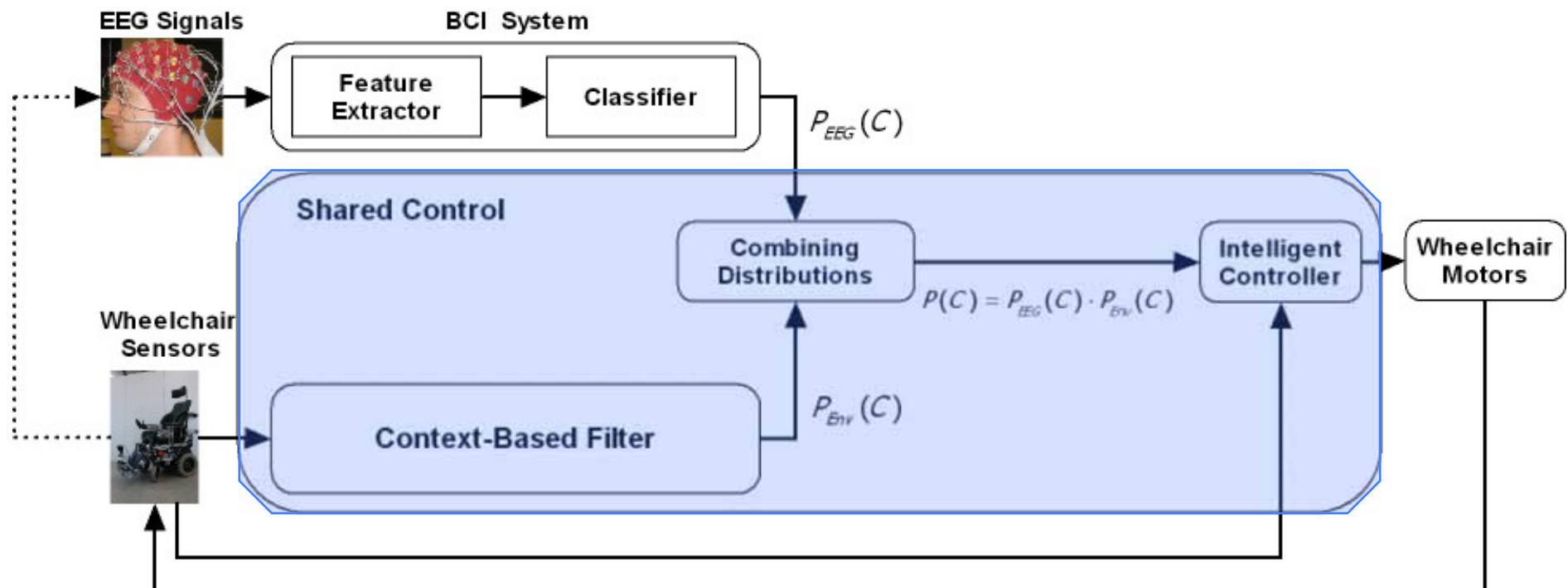
Users address the task at high level and all the low level details are handled automatically:

Intelligent Robotics





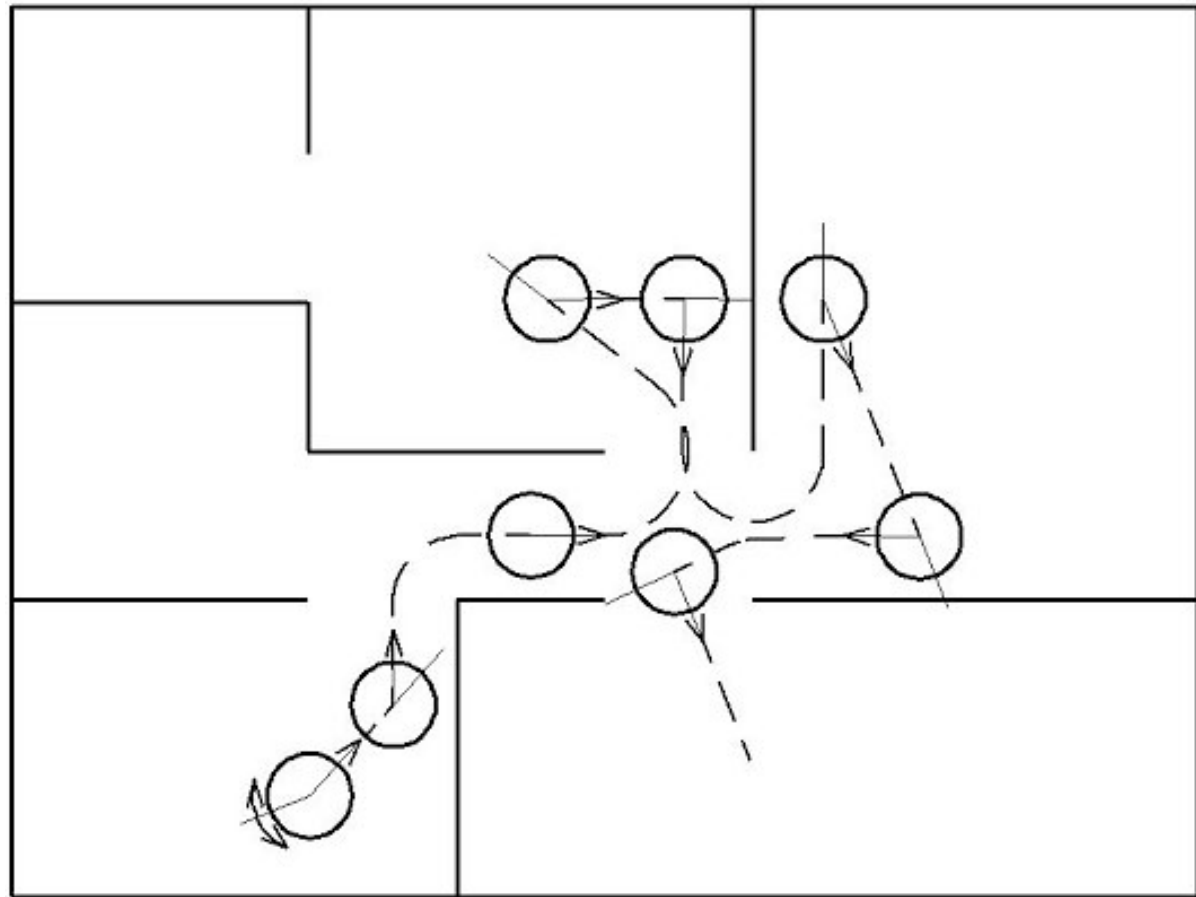
Adaptive Shared Control





Experiment I: Robot Navigation

*Qualitatively
good trajectories*





Experiment I: Execution Time (sec)

Subject 1
Relax, Left, Cube

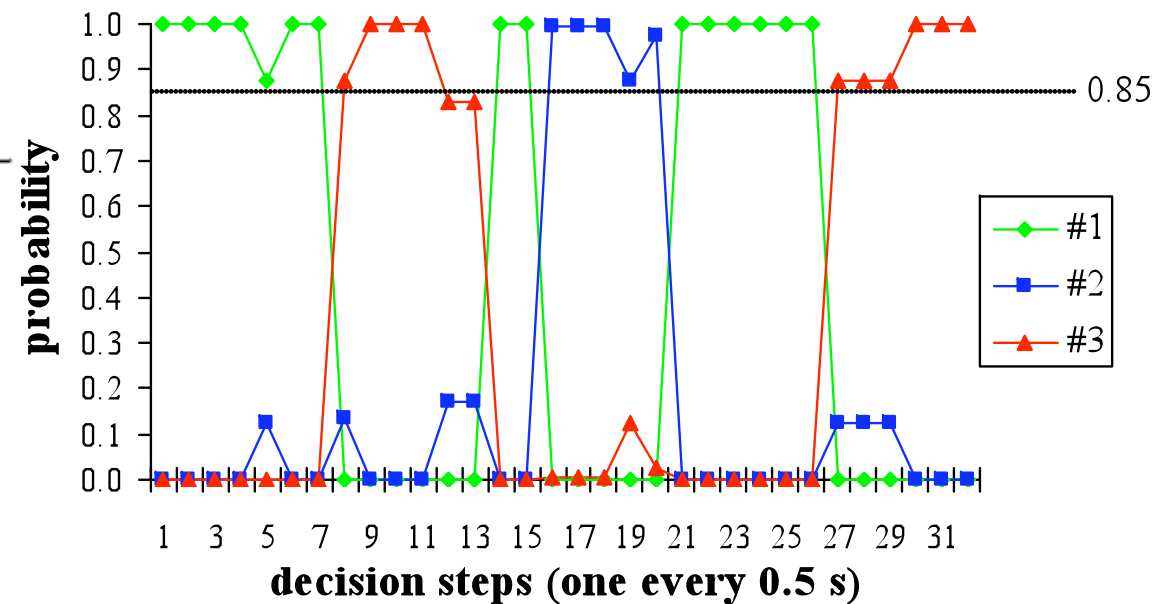
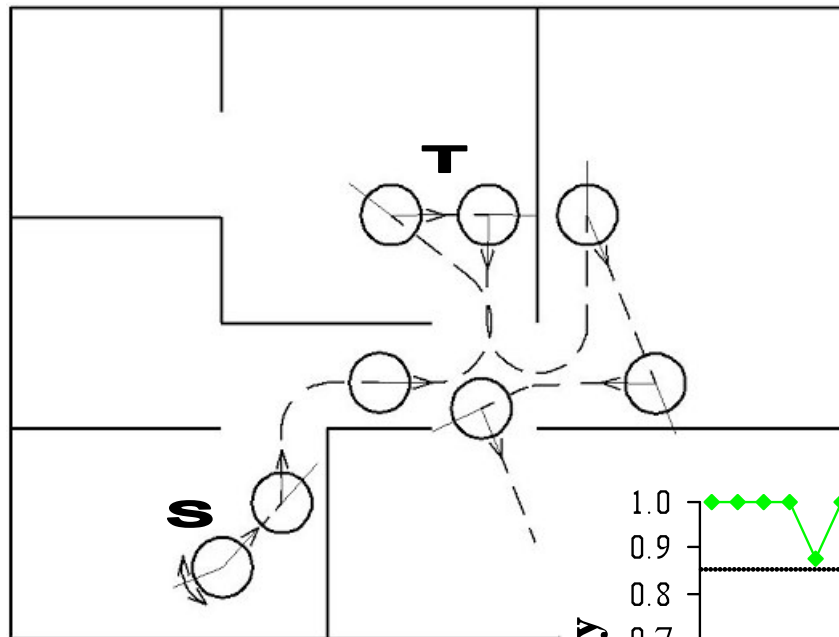
Trial	Mental	Manual	Ratio
1	149	124	0.83
2	183	135	0.74
3	191	129	0.68
Average	174	129	0.75

Subject 2
Relax, Left, Right

Trial	Mental	Manual	Ratio
1	219	156	0.71
2	189	155	0.82
3	175	117	0.67
Average	194	143	0.73



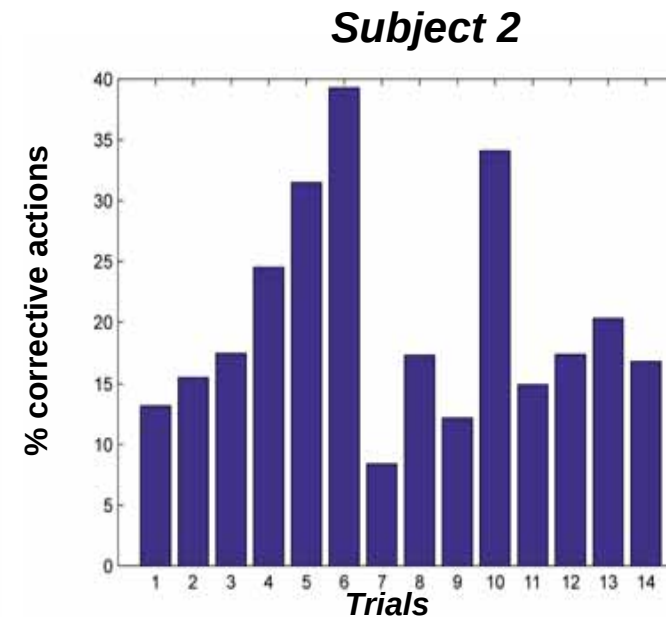
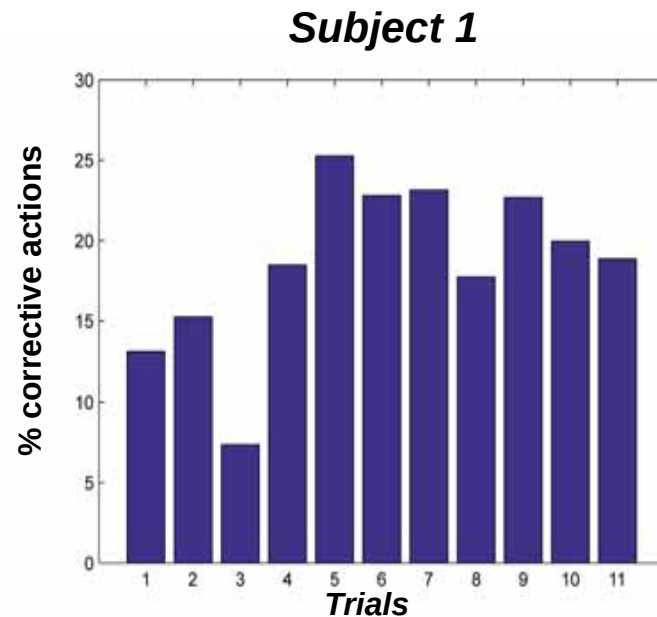
Experiment I: Fast Decisions





Experiment II: Wheelchair in Corridor

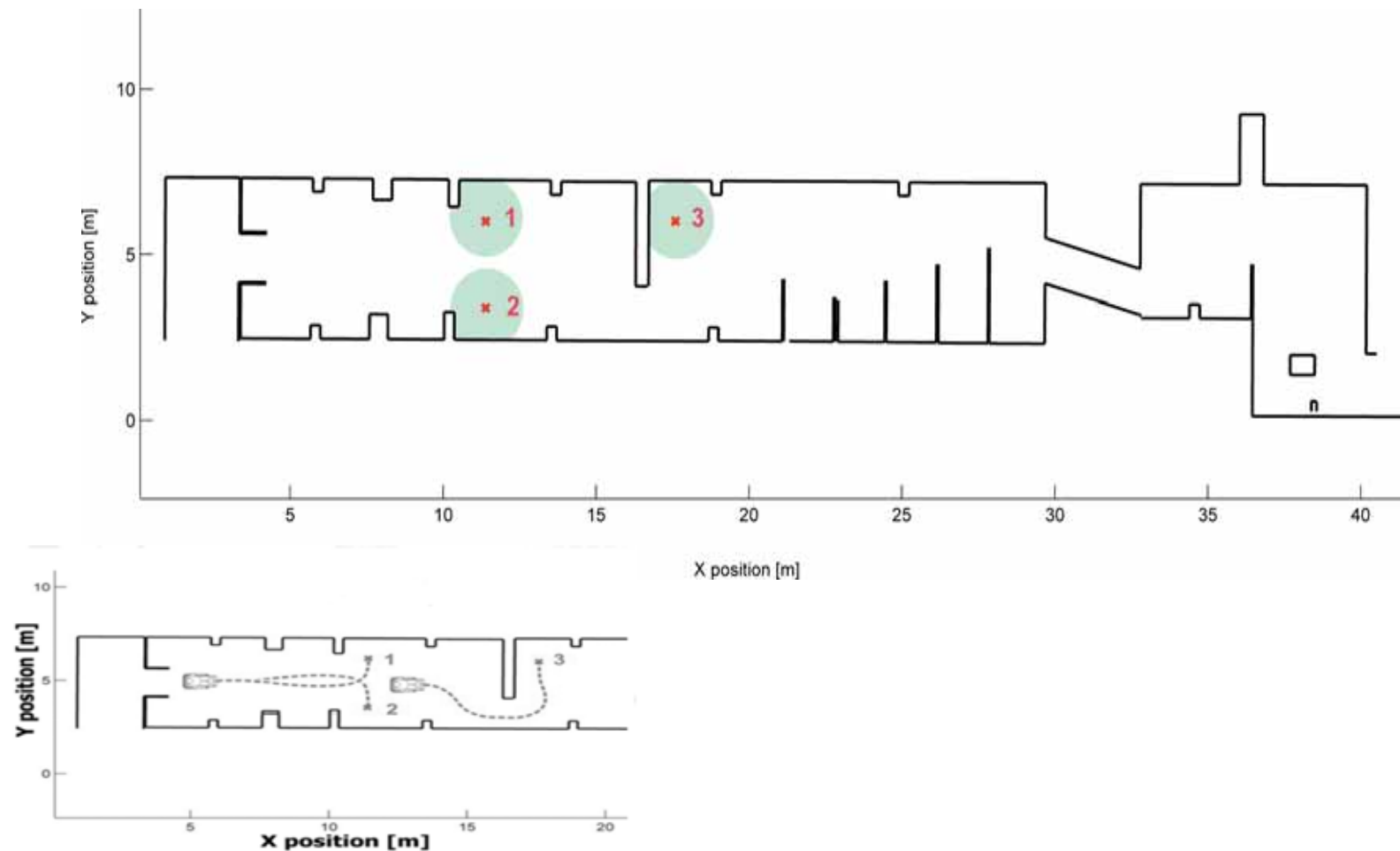
Percentage of corrective actions by Obstacle Avoidance behaviour (trial: ~250 - 350 seconds)



Variable level of assistance: it depends on context, fatigue, concentration, “exploiting” the assistance, ...

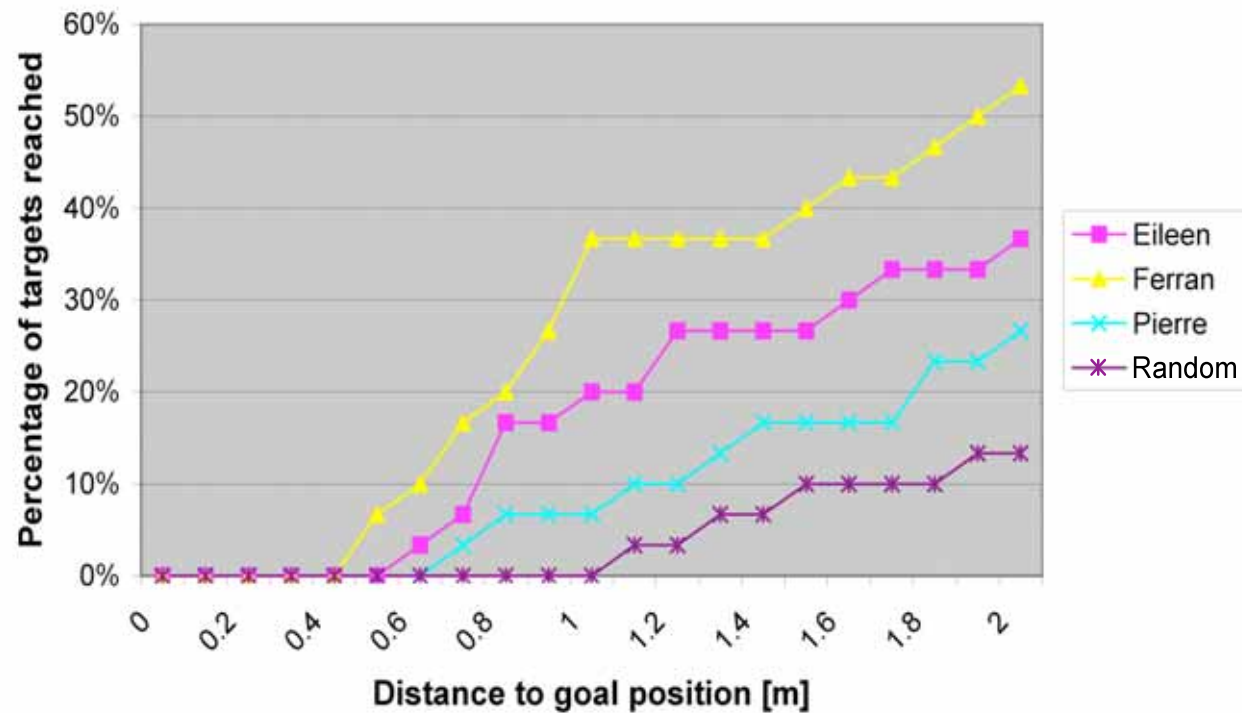


Experiment III: Wheelchair Docking





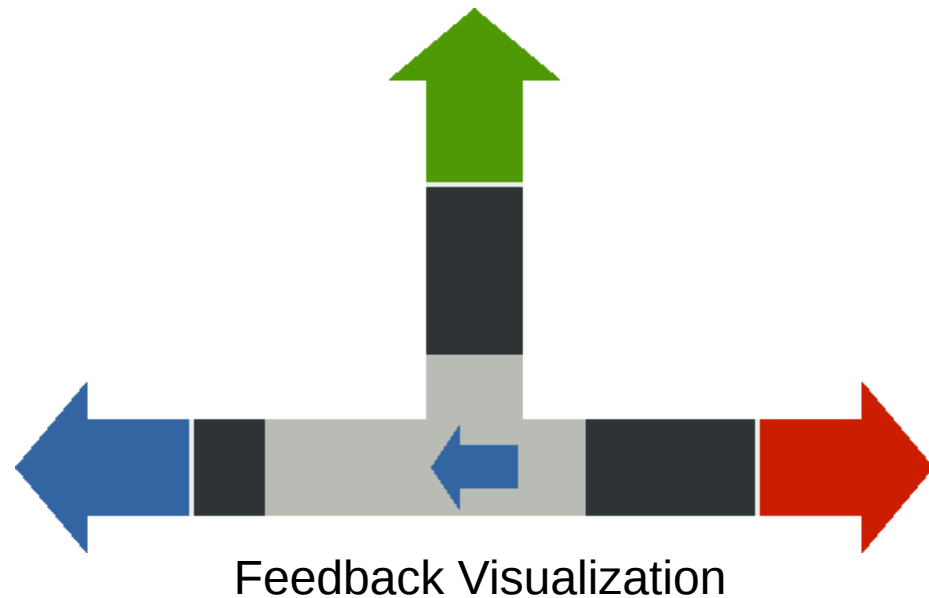
Experiment III: Wheelchair Docking





The Machine Learning Way: Invariances

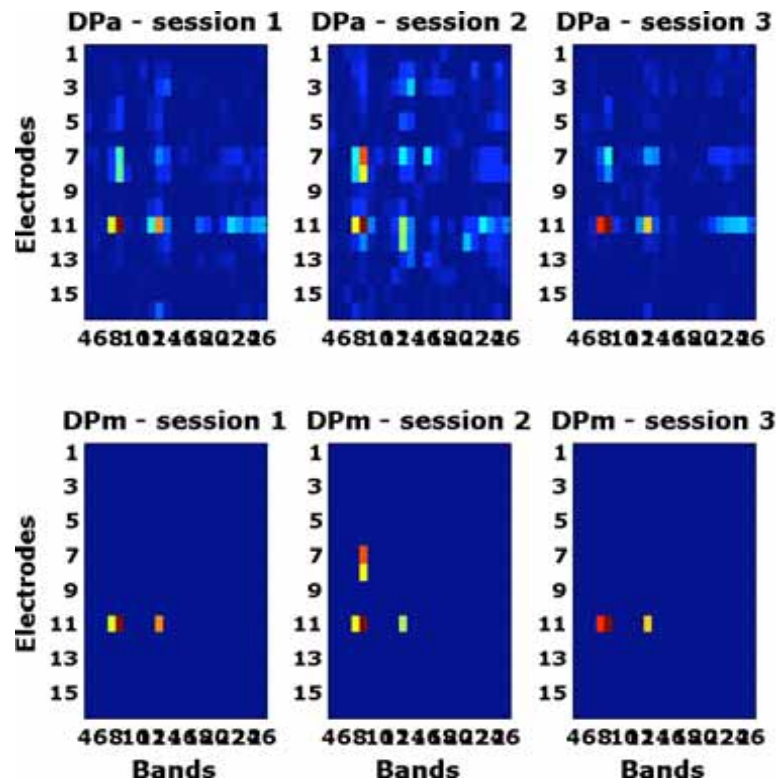
- Selection of stable discriminant features based on canonical variates analysis (CVA):
 - The subject selects 2 (3) motor imagery tasks she/he feels comfortable with
 - 4 sessions, fake feedback, ~20 minutes overall training time



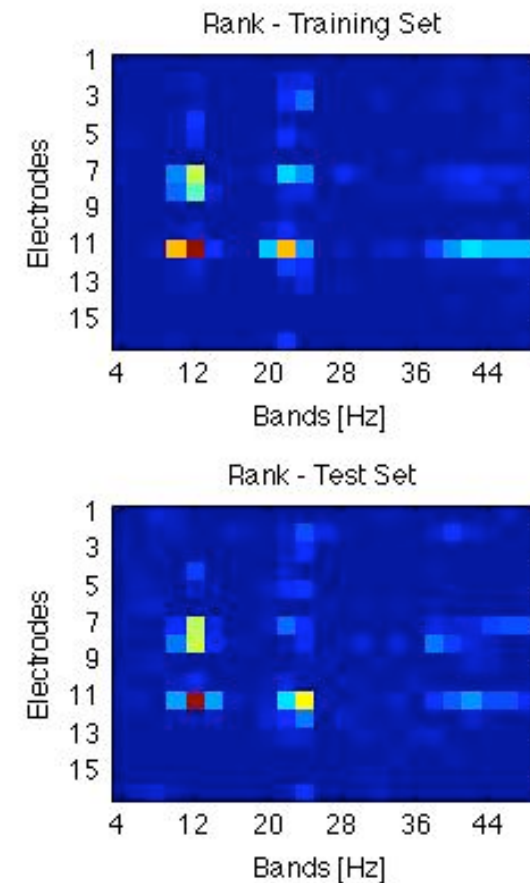


Stable, Discriminant Features

- Features ranked according to discriminant power
- Selected Features: high DP across sessions



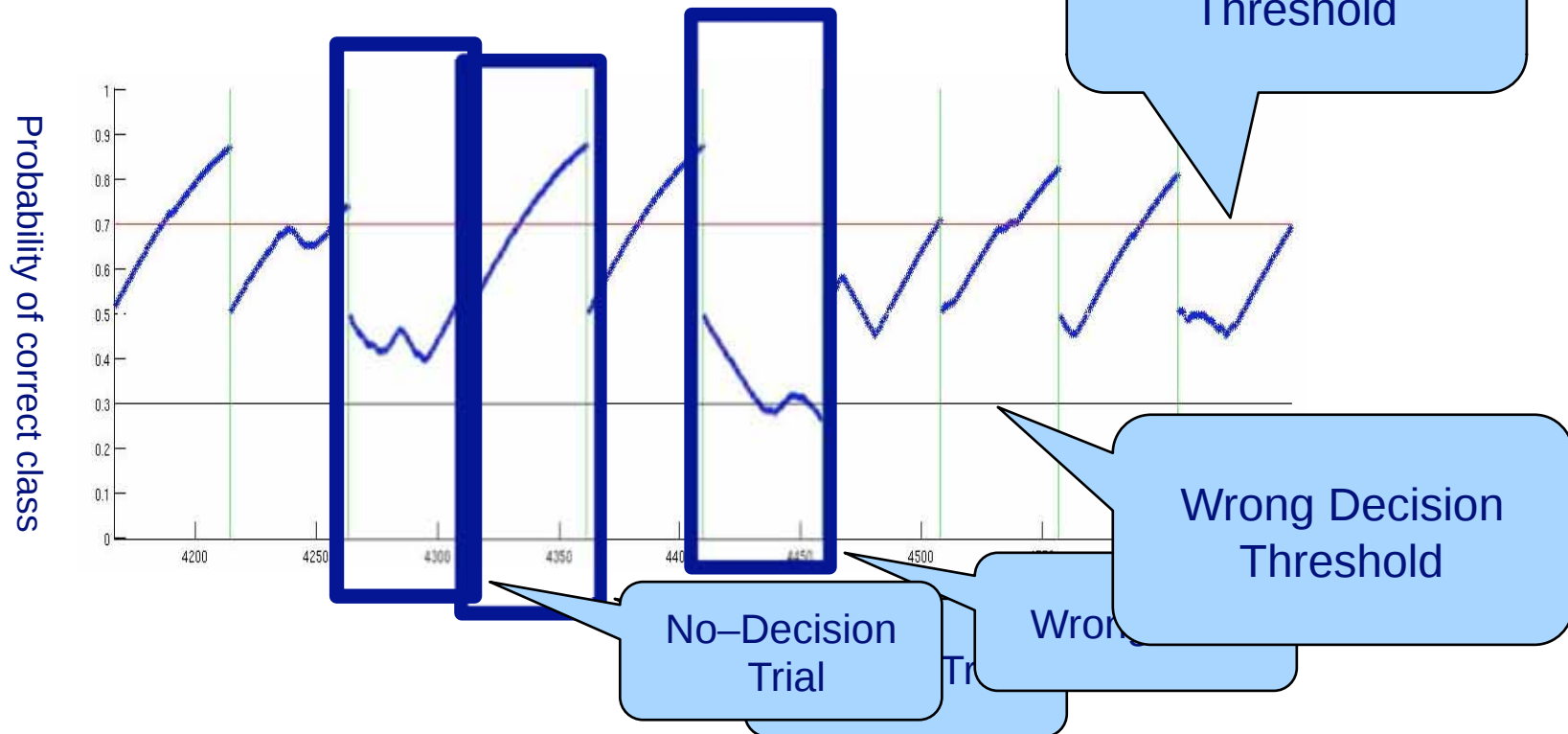
Across session stability





Evidence Accumulation for Probabilistic Decision Making

- Exponential Smoothing Integration:
 - Parameters: Smoothing coefficient, Rejection Threshold, and Decision Threshold

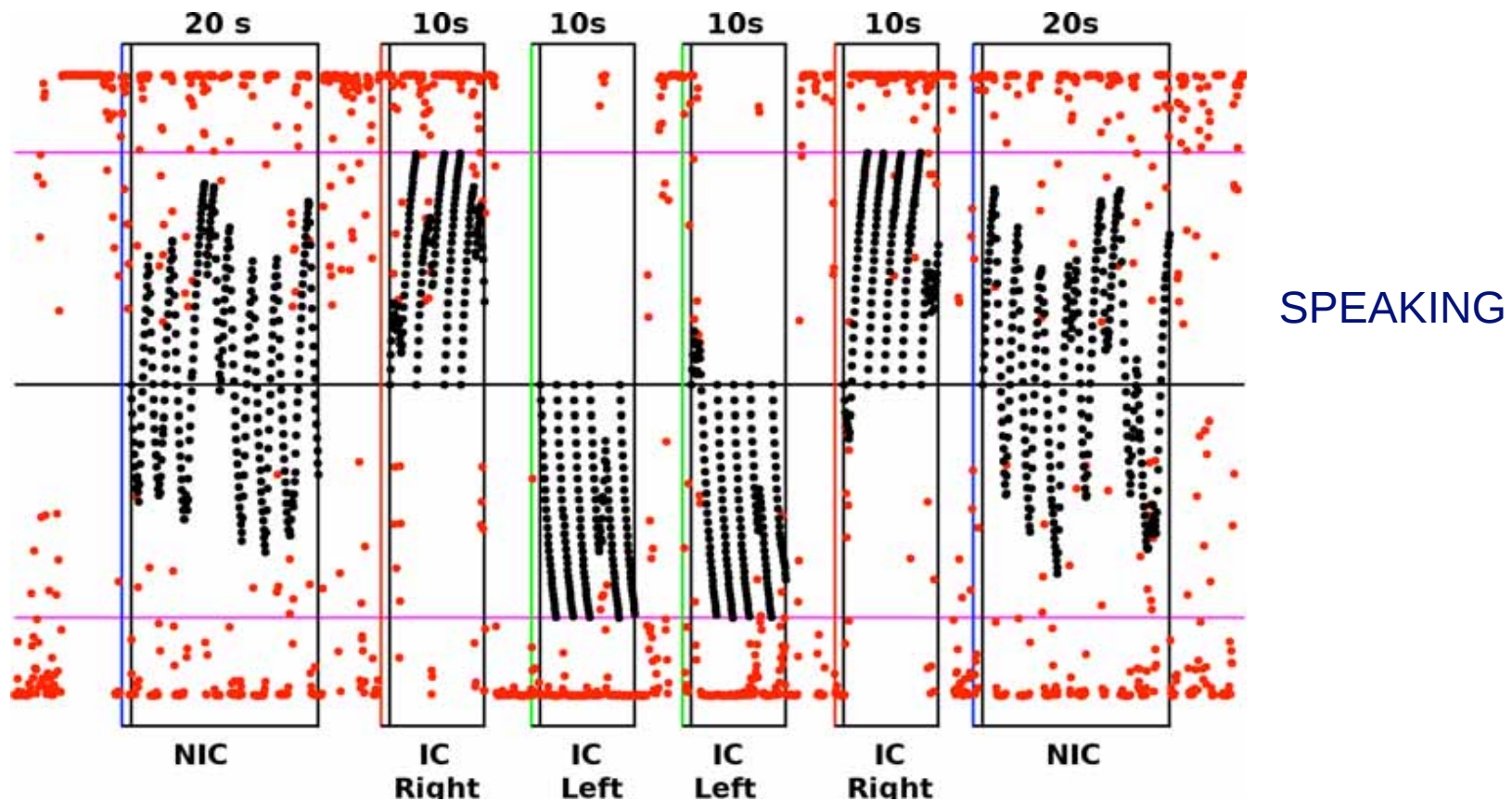




Multitasking & Intentional Non-Control

Michele Tavella. EPFL

- Preliminary results suggest our probabilistic approach allow subjects to perform *multitasking* and even achieve *intentional non-control*





Multitasking & Intentional Non-Control



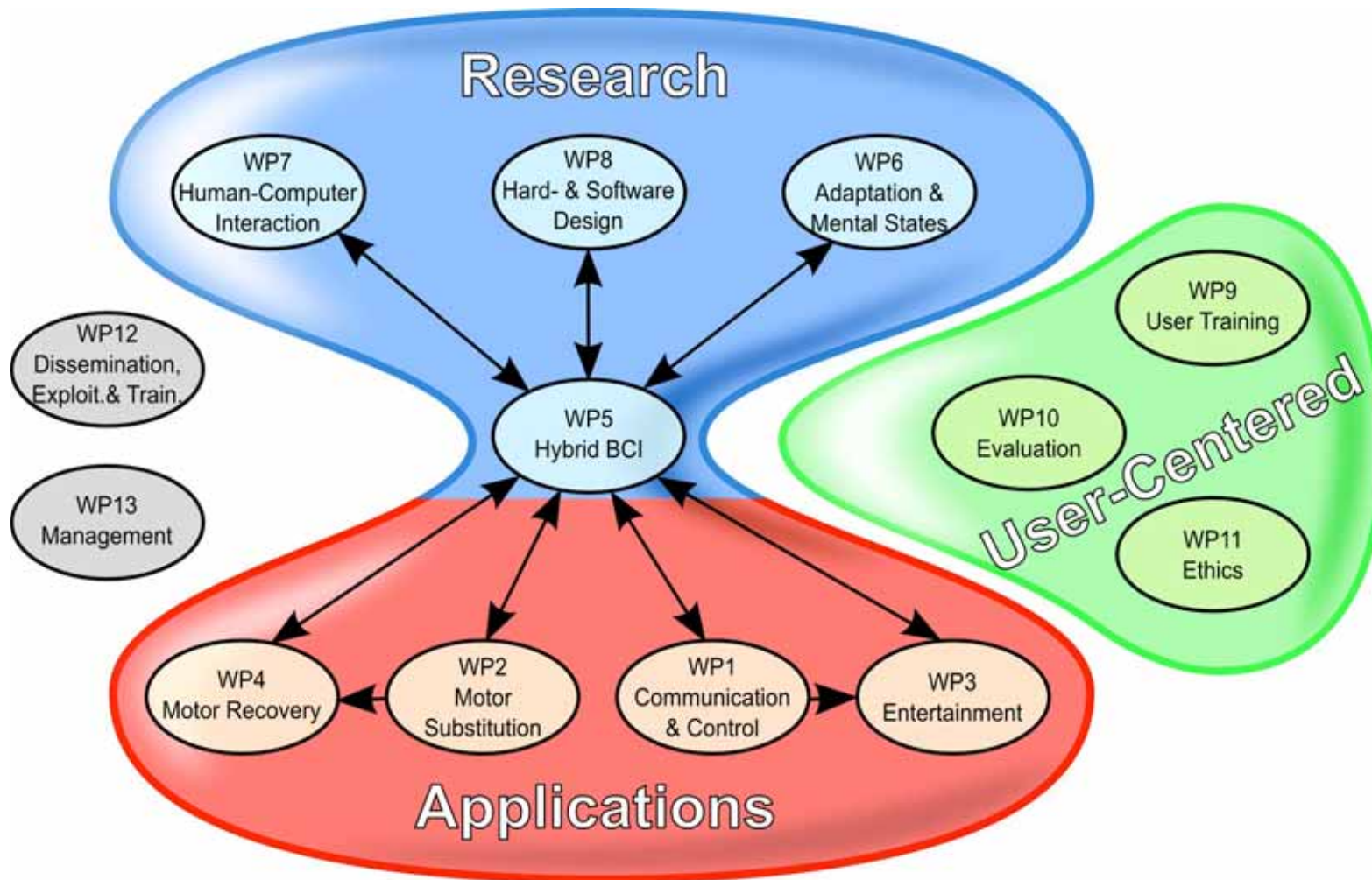


Conclusions

- ***Non-invasive neuroprosthetics*** — radical departure from current assumptions
 - Adaptive Shared Control, Machine Learning Way, Asynchronous Protocols, Cognitive Signals, Tactile Feedback
- ***EEG carries cognitive information*** — unique feature of the “brain channel”
 - It conveys information about **intents** (mental commands) **AND** **cognitive states** (errors, alarms, attention, fatigue, etc.) that are crucial for a purposeful interaction



TOBI Workpackages





Acknowledgements

- R. Leeb, M. Tavella, S. Perdikis, M. Gubler, M. Lostuzzo, L. Tonin
EPFL-CNBI, Switzerland
- P. Ferrez, F. Galán, E. Lew, R. Chavarriaga, G. Garipelli, N. Bourdaud, A. Buttfield
IDIAP / EPFL, Switzerland
- F. Renkens, A. Hauser, W. Gerstner
EPFL-LCN, Switzerland
- J. Mouriño, M. Franzé
Joint Research Centre, European Commission, Ispra, Italy
- F. Cincotti, D. Mattia, F. Babiloni, M.G. Marciani
Fondazione Santa Lucia, Rome, Italy
- M. Nuttin, G. Vanacker, J. Philips
Katholieke Universiteit Leuven, Belgium
- R. Rupp
Orthopedic Hospital, Univ. Heidelberg, Germany
- G. Müller-Putz, C. Neuper
Graz Univ. of Technology, Austria
- L. Kauhanen, T. Nykopp, M. Varsta, J. Heikkonen, K. Kaski
Helsinki University of Technology, Finland
- F. Topani
Fase Sistemi, Rome, Italy